Introduction to Psycholinguistics

Lecture 11

Language and embodiment

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Overview

- Re-considering modularity
  - Recall: Procedural modularity
    - Tanenhaus et al. , *Science* (1995)
  - The new "frontier": Representational modularity
    - Non-perceptual versus perceptually-related conceptual representations

e.g., Barsalou, 1999

- Neuropsychological evidence
- Behavioural evidence

Embodied cognition

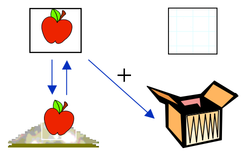
- Embodied accounts of comprehension have emerged from the more general movement of embodied cognition
- Wikipedia definition of embodiment
  - "Embodiment is the way in which human (or any other animal's) psychology arises from the brain's and body's physiology"
- Approaches towards defining embodied cognition
  - Six views of embodied cognition (Wilson, 2002), e.g.,
    - Cognition is situated
      - Cognitive activity occurs in a real-world environment, and it inherently involves perception and action
    - Cognition is for action
      - The mind guides action, and cognitive mechanisms such as perception contribute to situation-appropriate behavior
- Comparing the embodied approach with the visual-world studies from the last lecture

Procedural versus representational modularity

- Recall a key finding from visual world studies
  - Visual referential context rapidly influences structuring of an utterance

Tanenhaus et al., 1995

Put the apple on the towel in the box.



- Similarity
  - Emphasis on goal-directed action in the environment
- Difference
  - Implications for the **time course** with which scene information influences syntactic structuring but not necessarily implications for the **kinds of representations** used for comprehension

Amodal conceptual representations

- The default assumption in theories of conceptual representations has traditionally been that conceptual representations are *amodal* (i.e., non-perceptual)
  - ➪ Internal structure does not resemble the perceptual states from which they originate
  - ➪ E.g., amodal representation of the colour of an object in the absence of that object is located in a different neural system from the representations of that colour during the process of perception

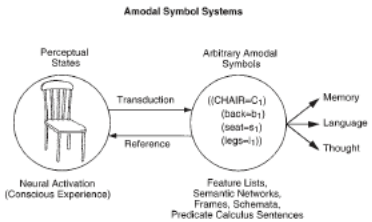


Figure 2. The basic assumption underlying amodal symbol systems: Perceptual states are transduced into a completely new representational system that describes these states amodally. As a result, the internal structure of these symbols is unrelated to the perceptual states that produced them, with conventional associations establishing reference instead.

Fig. from Barsalou, *BBS,* 1999

Perceptual symbol systems

- An alternative approach is a *perceptual* theory of cognition
  - ➪ Conceptual representations rely on perceptual representations, i.e., these representations overlap substantially
- Example
  - ➪ Barsalou, 1999: Theoretical framework for the embodiment of knowledge (not primarily language processing!)

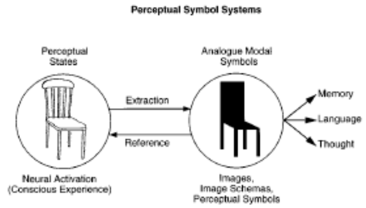


Figure 1. The basic assumption underlying perceptual symbol systems: Subsets of perceptual states in sensory-motor systems are extracted and stored in long-term memory to function as symbols. As a result, the internal structure of these symbols is modal, and they are analogically related to the perceptual states that produced them.

Fig. from Barsalou, *BBS,* 1999

Perceptual symbol systems

- The main goal of Barsalou's 1999 paper is
  - ➪ To demonstrate that perceptual symbol systems can achieve what amodal systems can achieve
- Some advantages of amodal symbol systems
  - ➪ Represent *types* and *tokens*
  - ➪ *Productive* combination of symbols to produce infinite number of conceptual structures
- Problematic issues with amodal symbol systems
  - ➪ No account for how perceptual states are converted into amodal symbols
  - ➪ Difficulty in representing spatio-temporal information
  - ➪ Empirical evidence against amodal systems
    - Damage to visual system disrupts processing of words whose referents are primarily processed visually (e.g., bird)
    - We'll hear about some more evidence later in the lecture …

Perceptual symbol systems

- Problematic issues with amodal symbol systems
  - ➪ Symbol grounding problem: mapping of symbols back into the world
    - Not clear how amodal symbols get mapped back onto entities in the world
      - ➪ Related: absence of physical referents in most amodal theories makes grounding problematic
    - One solution: associations between amodal symbols and perceptual memories
      - ➪ Perception of a dog activates perceptual memories which activate the amodal symbol for dog
      - ➪ During symbol grounding the activation of the amodal symbol activates associated perceptual memories which ground comprehension
    - Argument from perceptual side
      - ➪ Perceptual symbol systems can do all of this without amodal symbols
- Well, if perceptual symbol systems are **that** good, why haven't theories traditionally relied on them?

Perceptual symbol systems

- Barsalou argues that perceptual symbol systems have typically received little support for specific reasons
  - Perceptual symbol systems typically construed as *recording* systems rather than *conceptual* system
- Recording versus conceptual systems
  - Recording system only makes a copy of an object
  - In contrast, conceptual system **interprets** the entities in a recording
    - Example
      - Perceived objects (e.g., tree) are construed as instances of the type TREE
      - Through binding of perceived tokens to types in long-term memory
- Perceptual theory of knowledge based upon a conceptual system

Perceptual symbol systems

- Barsalou 1999 provides a **high-level account** of how a perceptual symbol system might function
  - Through selective attention, schematic representations of perceptual components extracted from experience and stored in memory (individual experiences of, e.g., purr)
    - Memories of the same component become organized around a common *frame* and implement a simulator
    - A *simulator* produces limitless simulations of the component (e.g., purr)

Core properties of perceptual symbol systems

- Notion of a frame
  - Integrates perceptual symbols across category instances
  - Can produce potentially infinite simulations of a category
  - Frame + the simulations it produces constitute a simulator
- Notion of a simulator
  - Spatially & temporally organized
    - Spatial: Car from the side/front
    - Temporal: “Accelerating” as a sequence of perceptual records: Press gas pedal, hear engine roar, let up the pedal and hear engine idle
  - Dynamic, i.e, varies with context and experience

Initial frame after first instance of a car

More elaborate frame after second instance

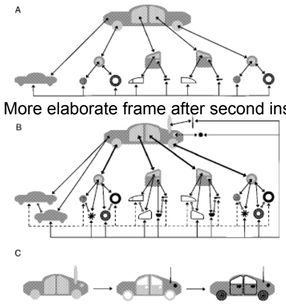
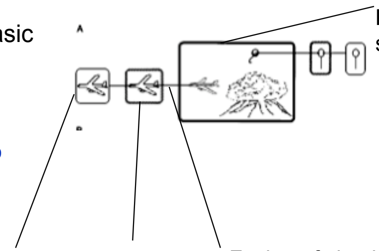


Figure 3. (A) An example of establishing an initial frame for *car* after processing a first instance. (B) The frame's evolution after processing a second instance. (C) Constructing a simulation of the second instance from the frame in panel B. In Panels A and B, lines with arrows represent excitatory connections, and lines with circles represent inhibitory connections.

Type-token mappings

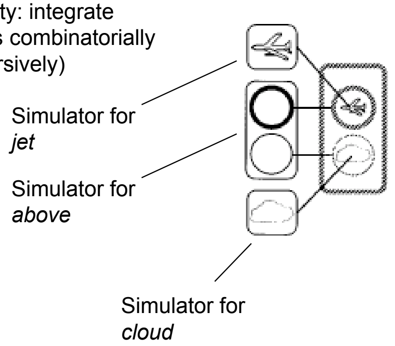
- Simulator implements basic conceptual system that represents e.g., types
  - Binding simulators to perceived individuals to represent type-token relationships



Combinatorial processes

- Simulators further support productivity
  - Productivity: integrate simulators combinatorially (and recursively)

"The jet is above the cloud"



Neuropsychological reality ...

- Of a Barsalou-type account?
- If we wanted to test claims that conceptual representations contain aspects of perceptual or motor representations ...
  - ➪ Which two hypotheses could we outline?
- Let's first look at **action understanding** (rather than language comprehension)
- Why - because those were what the first experiments that tested embodied-cognition claims focused on
- Action understanding
  - ➪ Form internal description of an action and use it to organize future behavior

Two hypotheses of action understanding

- Action understanding
  - ➪ Visual hypothesis
    - Analyse different elements of an action visually
    - Does not require motor involvement, and could rely on visual perceptual representations alone
  - ➪ Embodied view: Direct-matching hypothesis
    - Map visual representations of the observed action onto motor representations of that action

see Rizzolatti et al., 2001

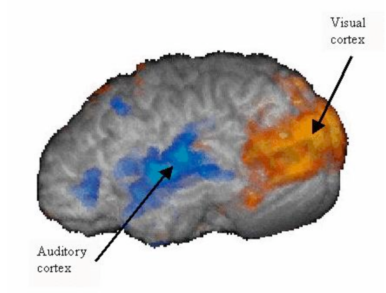
- Which measure would you chose?

Functional magnetic resonance imaging (fMRI)

- Technique for determining which parts of the brain are activated by different types of physical activity
  - ➪ E.g., sight or bodily movement
- Measures increased blood flow to the activated areas of the brain
  - ➪ Participant lies in the magnet and, for instance, views pictures
  - ➪ Then, MRI images of the participant's brain are taken.
  - ➪ A first scan is taken as a baseline that is used later as a background for highlighting the brain areas which were activated by the stimulus
  - ➪ Next, a series of further scans are taken during physical activity
    - For some of these scans, the stimulus (e.g., a picture) is presented, and for some of the scans, the stimulus will be absent
    - Comparison of +stimulus and -stimulus scans permit to see which parts of the brain were activated by the stimulus

fMRI

- FMRI permit us to identify the brain regions that become more active during the performance of specific tasks
- Example
  - Participants listened to spoken sentences while watching a screen with a flashing checkerboard
  - Onset and offset of sentences differed from those of the flashing picture
  - Time-locked activation in the brain permitted to identify the areas responsible for hearing and vision



http://www.fmrib.ox.ac.uk/fmri_intro/fmri_intro_files/image006.jpg

Motor resonance in cognition

- Theories of embodied cognition
  - Perception/understanding of actions involves the mental simulation of the action
- Neural mechanism that performs simulation-like motor processes?
  - *Mirror neurons* are neurons that respond both when a particular action is performed and when the same action performed by another individual is observed
  - *Mirror neuron system:* maps visual information (e.g., from a perceived action) onto its motor representation in the nervous system
    - First found in the premotor cortex of the macaque monkey both when the monkey performed and observed sb. else performing an action
    - In the meantime the above finding has been replicated for humans
    - Involvement of motor activity has been termed *motor resonance*

see, e.g., Rizzolatti et al., *Nature Reviews Neuroscience,* 2001

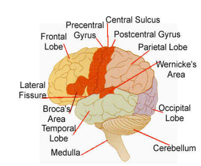
Motor resonance in language comprehension

Tettamanti et al., 2005

- Theories of embodied comprehension
  - Does comprehension of action language involve the mental simulation of actions?
- Method
  - fMRI study on 17 healthy, right-handed, native Italian speakers
- Task
  - Passive sentence listening
- Materials
  - Sentences describing actions performed with the
    - Mouth: Mordo la mela"; 'I bite an apple'
    - Hand: "Afferro il coltello"; 'I grasp a knife', or
    - Leg: "Calcio il pallone"; 'I kick the ball'
  - Abstract sentences of comparable syntactic structure as controls
    - "Apprezzo la sincerita`"; 'I appreciate sincerity'

Recall briefly from Lecture 1 … Cortical lobes

Front



Back

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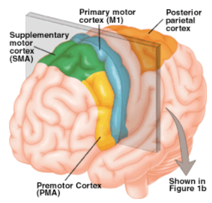


- **Frontal lobe**
  - Separated from parietal lobe by central sulcus/rolandic fissure
  - Contains Broca's Area
- **Parietal lobe**
  - Integrating sensory information
  - Manipulation of objects
  - Visuo-spatial processing
- **Temporal lobe**
  - Separated of frontal and parietal lobes by the lateral/sylvian fissure
  - Wernicke's area
  - Involved in hearing
  - Damage can result in problems processing auditory language
- **Occipital lobe**

fMRI during comprehension of action sentences

Tettamanti et al., 2005

- Listening to action-related sentences
- Activates a left **fronto-parieto-temporal** network
- Includes amongst other regions
  - ➪ Broca's area
  - ➪ Sectors of the premotor cortex where the actions described are motorically coded
- Interpretation
  - ➪ Involvement of visuo-motor circuits (subserve action execution and observation) during comprehension of sentences that describe actions

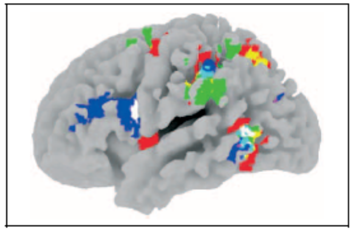


Figure 2. A lateral view of the average anatomical T1 image showing the activations in left inferior parietal and left middle temporal regions found at a lowered statistical threshold, in agreement with the experimental a priori hypothesis ($p < .005$, uncorrected; see Figure 1 for color codes).

White: action-related effects irrespective of Body parts

Blue: mouth-related
Red: hand-related
Green: leg-related

fMRI during action observation

- To summarize …
  - ➪ Neuronal evidence from a range of studies suggests that the processes underlying perception and action share a common representational framework
- Observers appear to understand the actions of another individual in terms of the same neural coding that they use to produce the same actions

Further behavioural findings

- Participants listened to sentences such as
  - ➪ "He opened the drawer"
- Task
  - ➪ Sensibility judgments ("Does the sentence make sense?")
  - ➪ Response by pressing a button
  - ➪ The button-pressing movement required either movement toward or away from their body
- Findings: action compatibility effect
  - ➪ Faster reaction times when behavioral response was in the same direction as the movement implied in the sentence

Glenberg & Kaschak, 2002

Motor resonance in action perception

Zwaan & Taylor, 2006

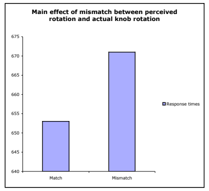
- Does the percept of visual rotation activate the motor programs that bring about this visual effect?
- If manual rotation affects visual mental rotation
  - ➪ Suggests a relation between manual and actual visual rotation
- Experiment procedure
  - ➪ Subjects observed a rotating black cross on the computer screen
  - ➪ Twisted a knob as soon as the cross changed color
- Design
  - ➪ Congruence between manual and visual rotation (match, mismatch)
  - ➪ Rotation direction (Clockwise vs. counter-clockwise)

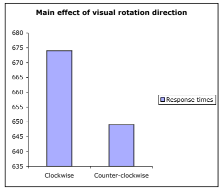
Results

- Measure
  - Response times

- If the actual rotation matched the perceived rotation then response times were faster

- Color changes during counter clock-wise rotation detected more faster than for counter-clockwise rotation
  - But: this effect might be due to the fact that clockwise and counter-clockwise conditions contained very different sentences



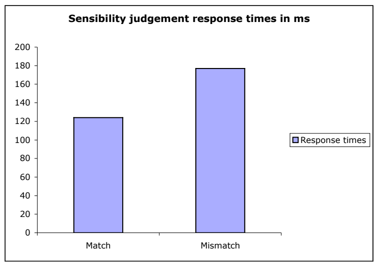


Motor resonance in sentence comprehension

- Does the observation of visual rotation affect the comprehension of sentences expressing a manual-rotation event?
- Example stimuli
  - Counter clockwise
    - Vincent dimmed the lights.
  - Clockwise
    - Dennis turned on the lamp.
- Participants made sensibility judgments while concurrently monitoring the rotating cross for color changes
  - Responded to colour changes with space bar
  - Two further buttons pressed to make sensibility judgements
- Visual rotation implied in the sentence either matched or mismatched the visual rotation of the cross

Results

- Significant congruence effect
  - Comprehension of sentences easier when
    - concurrent visual stimulus rotated in the same direction as the manual rotation implied by the sentence
    - compared with a stimulus rotating in the opposite direction



Motor resonance in sentence comprehension

- Evidence for motor resonance as evidenced by sensibility judgments at the end of the sentence
- But when exactly does motor resonance contribute to language comprehension?
  - Contextual information (from preceding linguistic input as well as information from the communicative context) becomes available immediately to the language processing system

    e.g., Chambers, Tanenhaus, & Magnuson, 2004
  - Alternatively, motor resonance might not occur until the end of the sentence

Motor resonance in language comprehension

- Duration of motor resonance?
  - “Turned down” in “Eric turned down the volume” triggers motor resonance
  - Does this resonance extend throughout reading of the direct object noun phrase?
    - It might extend since
      - End of sentence sensibility judgments have found a motion-language comprehension compatibility effect
    - Alternatively it might not last
      - Effect will be restricted to the verb, given that the noun phrase shifts attention away from the action to the acted-upon object

Time-course of motor resonance

- Frame-wise presentation of a sentence
  - Each frame showed between one and three words
  - Participants were able to move from one frame to the next by rotating a know
  - 5° of rotation made current frame disappear and a new one appear
  - Sentences described actions involving manual rotation
  - Knob-turning action either matched direction of rotation action in the sentence or not

To/quench/his/thirst/the/marathon/runner/eagerly/**opened**/the/water bottle,

Average reading times in ms per sentence region and condition

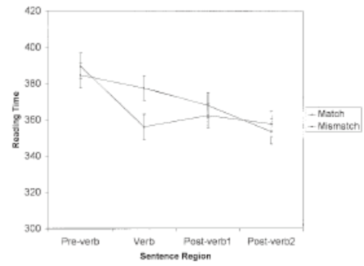
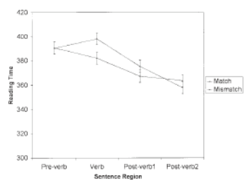


Fig. from Zwaan & Taylor, 2006

Time-course of motor resonance

- Does concurrent **visual** rotation produce reading time patterns similar to those for concurrent **manual** rotation?
- Illusionary rotation stimulus
- Procedure
  - A spacebar press triggered presentation of text blocks
  - Concurrent presentation of illusionary rotation stimulus
- Significant interaction between sentence region and match
  - Reading times for matching sentences < mismatching at verb region
  - No mismatch effects in other regions

Figure 2. Illusory rotation stimulus used in Experiment 5.



Average reading times in ms per sentence region and condition

Summary of the behavioural exps

- Concurrent visual rotation affected manual rotation
  - Congruent rotations were easier than incongruent rotations
- Concurrent visual rotation affects the comprehension of sentences about manual rotation
  - Responses were faster when the two rotations were in the same direction than when they were in opposite directions
- Fine-grained online measurements showed that motor resonance had dissipated before the end of the sentence (so maybe only a re-activation that leads to effects in the response times at the end of the sentence)

Conclusions

- Strong evidence for activation of motor representations during both action observation and comprehension
- Supports a Barsalou-type account
- To be investigated: the extend of motor resonance

- Last reading for this term
  - Tanenhaus et al. , *Science* (1995) (in the Seminar Ordner, Library)
- Next week
  - We'll review the course topics and outline which topics will appear on the exam